BROOKHAVEN NATIONAL LABORATORY
PROPOSAL INFORMATION QUESTIONNAIRE
LABORATORY DIRECTED RESEARCH AND DEVELOPMENT PROGRAM

PRINCIPAL INVESTIGATOR	**William W. MacKay**	PHONE	**3076**
DEPARTMENT/DIVISION	**CAD**	DATE	**5/03/2001**
OTHER INVESTIGATORS	**Pete Cameron,** **Roger Connolly**		
TITLE OF PROPOSAL	**Development of profile monitors for a high-current, low-energy-spread linac for electron cooling**		
PROPOSAL TERM From (month/year)	**10/2001**	To (month/year)	**10/2004**

SUMMARY OF PROPOSAL Provide an abstract of the proposed project which clearly defines the central idea of the project scope, its purpose and what it hopes to accomplish. Also indicate how it meets the general characteristics of the LDRD Program. This should not exceed the space given below. Attach an extended proposal of no more then two (3) pages in length plus a milestone schedule.

In order to upgrade the luminosity for RHIC we are developing the accelerator technology of high energy electron cooling. This is a cutting edge R&D, touching upon a number of issues that have never been tried. It includes the operation of a superconducting energy-recovery linac at an energy and current suitable for electron cooling of RHIC, that is 50 MeV and 100 to 200 mA. In order to tune the electron beam to have the correct characteristics for cooling the RHIC beams, we must be able to measure the emittance and optical functions of the electron beam. We propose to develop specialized electron beam diagnostics that will permit the nonintercepting beam profile measurements of a very high power, continuous duty electron beam. The electron beam in an energy recovery linac may not be interrupted since that will disrupt the recovery. We must obtain beam profile information at locations where synchrotron radiation is not observable. To do this we propose to extend techniques used for higher energy beams (GeV or greater) to lower energies (4 to 50 MeV) where the production and detection of photons becomes more difficult. Two methods will be investigated: imaging of synchrotron radiation and scanning the beam with a laser (Compton scattering). At the lower energies production of detectable synchrotron light becomes more difficult than at high energy. For 4 MeV electrons the Compton scattered photons are in the range of 100 eV, so we will most likely have to devlop a detector for use inside the beam pipe in close proximity to the pulsed high current electron beam.

Proposal

The Photoinjected Energy Recovery Linac (PERL) is a critical tool for a number of BNL future machines: the RHIC electron cooler, the PERL upgrade for the NSLS and for the eRHIC collider. The PERL is based on the union of two recent technologies: laser-photocathode rf guns (photoinjectors) and superconducting linear accelerators with beam energy recovery (Energy Recovering Linac).

The approach in this LDRD is to design and build prototype beam profile monitors to match the specifications of a high brightness electron source and recovery linac for an electron cooler. In order to measure the characteristics of the beam, several profiles will need to be measured at different energies and positions along the accelerator. At beam intensities of 100 mA foils for optical transition radiation can be destroyed, so we need to develop a nonintercepting monitor for profile measurements. Depending on the final lattice design synchrotron light monitors may be able to be used at some locations, although the production of detectable photons is considerably harder than at higher energies. Other locations may require measurements where there is little or no synchrotron light, so another method is needed. A tightly focussed laser beam has been used to scan high energy electron beams at the SLC by Compton scattering the laser off the multi-GeV electron beam. We plan to develop and optimize this technique for the much lower energy beam of the rf electron gun (~4 MeV). The scattered photons are soft x-rays which will require a detector within the beam pipe.

This research project will encompass the following points:

- Develop optimized synchrotron light monitors for the PERL at the top energy.
- Develop and test a laser scanner for electron beam profile monitors capable of handling the high-brightness, high-power low-energy electron beam.

LDRD Milestone Schedule	
Date	Planned Accomplishments
Six Months	Design of electron cooler lattice completed. Locations for profile monitors selected.
1 year	Prototype profile monitors designed.
2 years	Non-destructive electron beam diagnostics demonstrated at 4 MeV energy.
3 years	Non-destructive electron beam diagnostics demonstrated at 50 MeV energy.

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HUMAN SUBJECTS (Reference: DOE Order 1300.3) Y/N

Are human subjects involved from BNL or a collaborating institution?

If YES, attach copy of the current Institutional Review Board Approval and Informed Consent Form from BNL and/or collaborating institution. N

VERTEBRATE ANIMALS Y/N

Are vertebrate animals involved? N

If yes, has approval from BNL's Animal Care and Use Committee been obtained? Y/N

NEPA REVIEW Y/N

Are the activities proposed similar to those now carried out in the department/division which have been previously reviewed for potential environmental impacts and compliance with federal, state, local rules and regulations, and BNL's Environment, Safety, and Health Standards.
(Therefore, if funded, proposed activities would require no additional environmental evaluation.) N

Y/N

If no, has a NEPA review been completed in accordance with the Subject Area National Environmental Policy Act (NEPA) and Cultural Resources Evaluation and the results documented? N

(Note: if a NEPA review has not been completed, submit a copy of the work proposal to the BNL NEPA Coordinator for review. No work may commence until the review is completed and documented.)

OK

ES&H CONSIDERATIONS Y/N

Does the proposal provide sufficient funding for appropriate decommissioning of the research space when the experiment is complete? Y

Y/N

Is there an available waste disposal path for project wastes throughout the course of the experiment? Y

Y/N

Is funding available to properly dispose of project wastes throughout the course of the experiment? Y

Can the proposed work be carried out within the existing safety envelope of the facility (Facility Use Agreement, Nuclear Facility Authorization Agreement, Accelerator Safety Envelope [ASE], etc.) in which it will be performed? Y/N Y

If not, what has to be done to prepare the facility to accept the work (modify the facility, revise the SAR/SAD, revise the Facility Use Agreement, etc.)and how will the modifications be funded? Y/N

FUNDING REQUESTED [ATTACH A DETAILED BUDGET BREAKDOWN]

[Break down the funding by fiscal year and by the broad categories of labor, materials and supplies, travel (foreign & domestic), services and subcontracts. LDRD funds cannot be used to purchase capital equipment. Indicate the intent to use collaborators and/or postdoctoral students, if applicable. Identify the various burdens applied, i.e., materials, organizational contracts. The Laboratory G&A should not be applied.]

POTENTIAL FUTURE FUNDING

Identify below the Agencies and the specific program/office which may be interested in supplying future funding. Give some indication of time frame.

It is expected that the Department of Energy, Office of Science, Division of Nuclear Physics may be interested in supplying future funding. In a recent meeting of the NSAC in Santa Fe the Electron-Ion Collider and RHIC II R&D were rated very highly. Both initiatives have made high-energy electron cooling their top priority items. Thus it is expected that there will be DOE funding for the construction of an electron cooler at RHIC in a time-frame of about 3 years, and the broad community support for the Electron Ion Collider makes this possibly the next nuclear physics project in about 8 to 10 years.

Approvals

Department /Division Administrator ____________________

Department/Division Head ____________________

Cognizant Associate Director ____________________

BUDGET REQUEST BY FISCAL YEAR
(Note: Funding cannot exceed 3 years)

COST ELEMENT	FISCAL YEAR FY02	FISCAL YEAR FY03	FISCAL YEAR FY04
Labor * Fringe 37% Total Labor Organizational Burden @ 9.57 %	$ 121,004 44,771 $ 165,776 $ 15,865	$ 150,535 55,699 $ 206,234 $ 19,737	$ 157,309 58,205 $ 215,514 $ 20,625
Materials Supplies Travel Services Total MST Materials Burden @ 6.5%	$ 100,000 10,000 3,397 $ 113,397 $ 7,484	$ 50,000 7,867 3,000 $ 60,867 $ 4,097	$ 40,000 5,818 3,000 $ 48,818 $ 3,320
Sub-contracts Contracts Burden @ ____%			
Electric Power 1.99% CCD Charge 4.3% Other (specify) 22.35% (ODC 3.01 & Space 19.34%)	$ 3,299 $ 7,128 $ 37,051	$ 4,104 $ 8,868 $ 46,093	$ 4,289 $ 9,267 $ 48,167
TOTAL PROJECT COST	$350,000	$350,000	$350,000
* Labor (indicate type of staff and level of effort)	.42 FTE PHYSICIST .84 FTE ENGINEER	.50 FTE PHYSICIST 1.0 FTE ENGINEER	.50 FTE PHYSICIST 1.0 FTE ENGINEER
List all materials costing over $5000.	N/A	N/A	N/A

Extended Proposal

The types of profile monitors such as wire scanners and foils for optical transition radiation (OTR) which have been used in the TJNAF recovery linac (~5 mA) will not survive at the much higher currents of the PERL with electron currents of 100 to 200 mA. We propose to adapt two other types of profile monitors which have been used at high energies to the lower energies of the PERL (50 MeV or less) where they have not been used. Synchrotron light monitors are common in electron storage rings with energies in the GeV range and beyond. Compton scattered laser scanners have been used in the multi-GeV range at SLAC.

Description of Synchrotron Radiation Monitor:
For an electron of energy $E=\gamma mc^2$ moving through a bending dipole field B the critical energy of photons is given by

Missing picture

Table 1. shows approximate values for the energy of synchrotron radiation from typical bends after the electron gun and recovery linac for electron cooling of RHIC. The lower energy photons from the 4 MeV electrons have too low an energy to be readily detected by a detector, but at the top energy photons of 0.5 eV or more should be easy to detect with near IR detectors. A short permanent magnet wiggler could be developed and put into a drift section to produca e visible signal which may be imaged by a lens and camera system.

Table 1. Approximate values for synchrotron radiation from bends after electron gun and linac.

p [MeV/c]	B [T]	U_c [eV]	ρ [m]
4	0.1	0.001	0.13
50	0.3	0.5	0.56

Description of Laser Scanner Monitor:
For the lower energy beam from the gun (~4 MeV) we plan to scatter a finely focussed laser beam across the electron beam. The laser beam can be steered by moving a mirror or lens driven by a stepping motor. For a laser with photon energy of 1 eV crossing the electron beam at 90°, the Compton scattered photons will have a top energy of 120 eV peaked in the forward direction into a cone with an opening angle of about 130 mrad. Depending on the layout of magnets in the beam line, we may either place the photon detector downstream of a C-shaped bending magnet, or place the detectors around the beam in a straight section downstream of the laser crossing point. Since photons in the 100 eV range are likely to be stopped by a vacuum window, we will need to develop a detector internal to the vacuum which will be relatively insensitive to the pulsed charge of the nearby electron beam. By measuring the counting rate as the laser is scanned across the beam, we should be able to scan the transverse profile of the electron beam to a few tens of microns. (In this region the rms beam size will probably be 1 mm or more.) A laser scanner could also be used at the higher energies with a maximum scattered photon energy of 19 keV into a 10 mrad cone.

The typical rate of scattered photons from an electron bunch of 10^{10} electrons would be about

$$dN/dt = 50\ [\mathrm{Hz\ mm/W}]\ P/\sigma$$

where P is the instantaneous power of the laser and σ is the rms radius of the electron beam. (We have assumed a repetition rate of about 9 MHz for the electron bunches.) A modest laser with an instantaneous power of a few watts could produce a reasonable scan in a minute or less.